REPORT ON FIRE SAFETY OF THE WORLD TRADE CENTER

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January 1976

Report on Fire Safety at

The World Trade Center

* * *

Abstract

It has always been the Port Authority's intention to comply with Local Law 5 since it is our general policy to voluntarily comply with local building codes and in many cases to far exceed the specified requirements of same. A case in point is the World Trade Center project. Before enactment of Local Law 5 in 1973, the Port Authority staff and its hi-rise consultants studied the design of structures for life safety provisions and the following features were incorporated in the design and installed in the World Trade Center complex which were over and above existing code requirements at the time:

- Smoke detectors on each floor at return air ducts.
- Elevators return to ground floor for fireman readiness.
- Fire alarm boxes on each floor with voice communication.
- Public address system in corridors.
- Smoke purge configuration for air-conditioning system.
- Fire director's unit central control console.

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During the period of design, which began in 1967, the Port Authority worked closely with the New York City Fire Department on the development of these features as well as familiarization of the Fire Department with the

building systems and access. In 1970, the Port Authority further cooperated with the Fire Department by making the 30 Church Street building available, immediately prior to its demolition, for the Fire Department and its consultant to conduct controlled fire tests and evaluate the principle of stair pressurization to provide safe egress from a fire floor. Partially, as a result of these actual fire test conditions of stair pressurization, requirements for such a pressurization system were included in one of the options of Local Law 5.

After the World Trade Center fire last spring, Dr. Ronan appointed a Commissioners' Fire Committee headed by Commissioner George Berlinger, and including Commissioners Axtell, Gilbert and Hellmuth. This committee directed Port Authority staff to thoroughly review all aspects of the World Trade Center fire and the life safety provisions of the structures, including the conforming of the complex to the provisions of Local Law 5. The latter provides for the selection of either a compartmentation option or a sprinkler option. The committee further retained an independent consultant to review the World Trade Center life safety provisions.

The consultant concluded that the existing structural fire retardants of the building are sufficient to make the probability of serious structural damage extremely remote and that the degree of vertical compartmentation provided sufficiently limits the spread of fire in the structures, but that the spread of smoke requires attention from a life safety standpoint.

The consultant further concluded that...

> "The results of these comparative analyses indicated that, in our opinion, either of the two fire protection

options provided for under Local Law 5 would provide a good level of occupant life safety within the World Trade Center complex, provided that whichever is selected is supplemented by certain additional measures."

The additional provisions recommended by the consultant over and above the compartmentation option are summarized as follows:

1) Sprinklering of all rooms in the central corridor area which could contribute excessive quantities of smoke to the corridor systems;
2) Doors which are normally kept open to the corridor system should be equipped with electro-magnetic "hold-open" devices which would be activated to close the doors;
3) Provide fail-safe automatic door closers, arranged to close upon activation by smoke detectors for the overhead rolling fire doors separating the below grade truck dock from the elevator lobby;
4) Perform an investigation to determine the optimum mode of operation of the building air-conditioning system to remove smoke from the central core compartments without contaminating adjacent areas.

The additional provisions recommended by the consultant over and above the sprinkler option are items 2, 3 and 4 above and the following.

Provide automatic smoke detection in immediate vicinity of elevators at each floor level.

In a separate report, prepared by the New York Board of Fire Underwriters, an investigation of the February 13th, 1975 fire, the Board wrote:

> "The Fire Safety Program of the World Trade Center is an excellent one."

The Board, while recommending examination of additional safety measures, further observed:

> "In the overall, these towers may be considered as among the safest buildings in New York City."

As a result of the investigation and studies that have been performed, the Committee has decided to proceed immediately with the following steps in compliance with Local Law 5 and the additional items over and above Local Law 5 requirements as listed below:

A) Compartmentation option of Local Law 5 which includes the following major steps:

1) Expansion of fire alarm and communication system.
2) The installation of smoke detectors in elevator lobbies and additional smoke detectors at air return inlets.
3) Compartmentation of spaces into 7500 square foot areas.
4) Proceed with stair pressurization design and prototype pressurization testing in the structure for World Trade Center Towers.

B) Additional items over and above Local Law 5:

1) The implementation of all the recommendations from the consultant and staff.

2) Sprinkler all janitor closets, mail rooms, file rooms, storage rooms, etc. in the central core of each floor of each tower and make provisions for extension of sprinkler system to any areas of such usage requiring same as occupancy may change.

PART I

Report on Fire of February 13, 1975

Introduction

After the World Trade Center fire last spring, Dr. Ronan appointed a Commissioners' Fire Committee which consisted of Commissioners Berlinger, Axtell, Gilbert and Hellmuth. Commissioner Berlinger was appointed chairman of the committee. This committee directed Port Authority staff to thoroughly investigate and review the extent of the fire and smoke damage, the origin of the fire, the functioning of the building systems for prevention, detection and fighting of fires, and safety procedures. The Port Authority staff members appointed to carry out this assignment were Messrs. R. M. Monti, Chief Engineer; R. F. Abrahams, Chief Contract Division, Law; J. DeMarinis, Manager, Risk Management Division. The Commissioners' Fire Committee also retained the services of an independent consultant to review all safety aspects of World Trade Center operations regarding fire protection.

Development of the Fire

The fire started in the office of R. J. Saunders, Inc., Suite no. 1119. It extended north to two smaller adjacent offices, where it was stopped in that direction and extended to the southwest corner of the Saunders office, where it was stopped in that direction. A telephone closet containing vertical telephone cables, and other equipment is located adjacent to the Saunders mail area. The closet had a door with ventilation

louvers. This telephone closet communicated vertically with identical telephone closets above and below through an opening containing vertical telephone cables, and other equipment was located adjacent to the Saunders mail area. The closet has a door with ventilation louvers. This telephone closet communicated vertically with identical telephone closets above and below through an opening of about 1.5 square feet cut in the concrete slab. All such southeast telephone closets on floors seven (7) through forty (40) created a vertical opening within the building; their doors are normally kept closed. Fire extended to the inside of the 11th floor telephone closet and communicated to closets on floors above and below through the concrete slab openings, causing damage to telephone closets on the 10th, 12th, and 13th floors and lesser damage on the 9th, 14th, 15th and 16th floors. Ignition of the plastic insulation and the plywood boards, used for attaching the telephone equipment to the walls of the closet, occurred. The fire was then transmitted to the 10th and 12th floor closets. * While it must have taken some period of time for the fire to fully develop within this telephone closet, it must be noted that this area within the Saunders suite was probably the last reached by the fire department.

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* The openings in the telephone closets were necessarily left during construction for installation of telephone cable and were planned eventually to be closed up around the cables as soon as further cable installation was completed, e.g. for the television broadcasting facilities intended to operate at the top of Tower A. A contract for such closing has been awarded and the work has been completed.

In summary the chronological sequence of the observed events of the fire was as follows:

11:55 p.m., (Thursday, February 13): Cleaning porter in corridor observed fire under door of Suite 1119; he reported to the World Trade Center control desk via the fire alarm emergency telephone in the 11th floor corridor; New York City Fire Department notified and Port Authority police officers dispatched to the 11th floor, where they activated the building standpipe system and commenced to wet down the corridor door of Suite 1119.

12:01 a.m., first Fire Department units entered the World Trade Center.

12:09 a.m., Fire Department units arrived on 11th floor.

12:15 a.m., second group of Fire Department units arrived, in response to second alarm, transmitted by Fire Department officer on scene.

12:42 a.m., third group of Fire Department units arrived in response to third alarm, transmitted by Fire Department officer on scene; Fire Commissioner O'Hagan also arrived at this time.

3:22 a.m., Fire Department indicated all clear condition, after a floor to floor check up to the 41st floor.

The Fire Department used water from the World Trade Center building standpipe system, to which it connected its hoses. The Department stated that there was a sufficient supply of water for fire extinguishment.

Cause of Fire - Suspected Arson

In July 1975 a Temco Maintenance Company employee was charged in an indictment with setting the February 13, 1975 fire as well as five subsequent World Trade Center fires.

Extent of Fire Damage

The fire damage occurred mainly on the 11th floor, in the southeast quadrant. Whatever fire damage occurred on other floors was generally limited to the telephone closet in the southeast quadrant of floors 9 through 14 and a small portion of spaces immediately adjacent to the telephone closets.

Smoke damage occurred in varying degrees in the adjoining sections of the 11th floor; elsewhere, the significant smoke damage occurred on the 10th, 12th, 13th and 14th floors. Smoke damage on floors 15 through 23 was generally limited to the area of the telephone closet in the southeast quadrant and a small portion of the tenant spaces immediately adjacent, in decreasing degrees.

Existing Building System Evaluation -
World Trade Center Building System - Building Code

For further information there follows a description of the World Trade Center building systems for fire protection and extinguishment, together with an account of the Port Authority's conformance to the standards established by the New York City Building Code, including the amendments known as Local Law 5/73, even though the State and its agencies, such as the Port Authority, are not subject to City building codes.

References are made in various places to the 1968 building code, since that code would have applied to construction generally at the time the World Trade Center was built. A separate discussion addresses itself to the amendments of 1973, i.e. Local Law No. 5. Following is a description of the existing systems at the World Trade Center:

Air Distribution Systems

The Trade Center air distribution systems, in addition to conforming to all the 1968 NYC Building Code requirements, also possess an additional mode of operation which can be utilized to assist in controlling smoke from a fire. In this mode the return air shaft and fan systems are used to exhaust from the office spaces to the exterior of the building. The core system is also operated to provide outside air to the corridors.*

Fire Standpipe System

The standpipe system consists of manually activated fire pumps rated at 750 GPM each located at the Service Level, 7th Floor, 41st Floor and 75th Floor. In addition, there

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* There are four mechanical equipment rooms serving each tower. These equipment rooms, which contain the air handling systems, are located on the 7th, 41st, 75th and 108th floors. The air distribution from these floors can be generally divided into three sub-systems, the peripheral, the interior and the core. The peripheral system serves the floor area around the exterior wall and feeds up from the ceiling of the floor below to induction units at the exterior wall. The interior system serves the remaining office floor area through ductwork located above the hung ceiling with air outlets combined with the light fixtures. Air returns to the equipment room through other light fixtures into the ceiling area, which acts as a plenum, and from the plenum to shafts running vertically at the building core. The core system serves the corridor and elevator lobbies.

are 5,000 gal. water storage tanks located on the 20th Floor, 41st Floor, 75th Floor and roof. There are also a minimum of three fire hose racks on each floor capable of reaching every part of that floor. The standpipe system conforms to the 1968 Building Code. Initially, during the fighting of the fire, Tower A pump experienced some difficulty with the speed control panel. Tower B pump, which was designed to be operable also for Tower A, was then used. The Tower A pump was returned to use during the fire fighting, without difficulty. The standpipe system functioned to the complete satisfaction of the Fire Department throughout.

Smoke Detectors

Smoke detectors were installed in each return air fan discharge duct and each supply unit. Upon actuation any one of these detectors will shut down all the ventilation fans within the respective quadrant of the mechanical room and initiate a print-out and visual and audible alarms in the central control station. This installation is in conformance with the 1968 Building Code.

In addition to the smoke detectors previously noted, under a contract prepared prior to enactment of Local Law 5, detectors with supervised circuits have been installed at 4 locations on each floor of the Tower Buildings. These detectors are located above the hung ceiling directly in front of a return air duct intake and indicate an alarm condition, by floor, at the Port Authority Police Desk. In the building zone in which the fire occurred, detectors were installed and operational on Floors 9 through 19. These detectors initiated a print-out at the police desk.

Elevator Control

All passenger elevator cars are capable of being recalled to their respective lobbies. This control over-rides all individual floor hall calls, prevents heat from calling a car to a "fire floor" and makes the car available for manual operation by building personnel and the Fire Department.

This is in excess of the requirements of the 1968 Code, which required only one elevator capable of serving each floor equipped for emergency return and Fire Department Service.

Fire Alarm System

On each floor of each of the World Trade Center buildings, at a central corridor location, there was a fire alarm emergency telephone which connected with a control center next to the Police Desk on the lower level of Tower A. (In addition, the Port Authority has applied on telephones in its own offices, and has distributed to tenants for their application on their telephones, a conspicuous red label giving the telephone number of the Police Desk to call in case of emergency.) An interior fire alarm system including voice communication has been installed on each floor in the core corridor. Incoming fire calls to the control center illuminate the indicating lamp of a particular fire station and sound an audible signal. In addition, an emergency public address system provides communication from the control center to all locations equipped with loudspeakers, as selected by the control center operator. The system also can transmit, through two individual microphones, different messages to selected loudspeaker areas. It can also receive communications from the elevator starter panels. Pre-recorded announcements can be transmitted through this system and announcements originating from the elevator starter panels can be transmitted through this console to selected loudspeakers. Fire alarm warble tones can be transmitted to any floor or floors from one of these microphones.

The control console is equipped with separate indicator lights and switches for each area. The indicating lights provide visual information as to which loudspeaker area is in operation. In addition, a warning light system is included to indicate failure of any of the amplifiers located in a remote location. These amplifiers are tested automatically at intervals or can be tested manually by operating personnel. Visual indication of amplifier failure is also provided on the front panel of each power amplifier.

Requirements of Local Law No. 5/73

The fire safety amendments to the New York City Building Code embodied in Local Law 5 adopted in 1973 prescribe various measures to be complied with by various dates. The Port Authority has complied with those for which compliance dates have already occurred, and in fact had incorporated in the World Trade Center design a number of such measures before they were adopted under Local Law 5. Some examples are as follows.*

Interior fire alarm system, including voice communication:

The World Trade Center was designed and constructed with a fire alarm and voice communication system in the corridors before any such system was required by code. Local Law 5 required such a system to be installed, including its extension into office spaces as well as stairways. A contract has been prepared and awarded to extend the system into the office spaces and stairways.

Automatic "homing" of elevators, and elevator in readiness:

Manual controls presently installed in the World Trade Center permit recall of all elevators to their home floor, overriding any manual or heat activation of call buttons, where they can be placed under the command of the Fire Department for fire fighting operations. This too was beyond the requirements of the 1968 code. Local Law 5 now requires automatic homing of elevators when

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* While combustibility of furnishings is not dealt with in Local Law 5 or other parts of the New York City Building Code, the Port Authority addressed itself to this problem in planning the World Trade Center and after extensive study adopted and applied standards rigidly limiting its own furnishings to a low rate of flammability. A copy of the Port Authority's flammability standards was communicated to tenants, pointing out the advisability of their use.

a smoke detector, to be installed in the elevator lobby of each floor, is activated. Such additional smoke detectors and automatic activation will be installed at the World Trade Center.

Sprinklers or Compartmentation and Other Measures

Under Local Law 5, owners of buildings (existing and future) of a class in which the World Trade Center would be included, are given the option of sprinklering throughout or of installing certain measures such as compartmentation of each floor into maximum areas of 7,500 square feet each separated by fire rated partitions, as well as smoke detectors as above described and pressurization of stairwells.

In certain types of locations, such as below grade areas and restaurants, and other commercial spaces, sprinklering is required without allowance for an option, and in those locations the World Trade Center as originally constructed included sprinklers.

Fire Safety Plan

Local Law 5 calls for a plan of regular fire drills and evacuation procedures, approved by the City, under the supervision and control of a building fire safety director and one or more deputies. The Port Authority's plan exceeds these requirements, and the New York Board of Fire Underwriters, after investigating the February 13th fire, observed: "The Fire Safety Program of the World Trade Center is an excellent one." The Board, while recommending examination of additional safety measures, such as limiting combustibility of furnishings, further observed: "In the overall, these towers may be considered as among the safest buildings in New York City." See Page 10 of The New York Board of Fire Underwriters report.

* * *

PART II

Evaluation of Life Safety

The World Trade Center contains a complete fire protection and life safety installation which is itemized in the following sections. Furthermore, as indicated herein, additional measures will be implemented to enhance the present standards.

1. Existing Life Safety Features

As noted in Part I of this report, the World Trade Center has extensive life safety features which are in accordance with and beyond the requirements of New York City Code. These features include the following:

- fireproof construction
- fire standpipe system
- smoke purge mode for air conditioning systems
- fire alarm and voice communication system
- sprinklers for restaurants, concession areas, and other public areas
- elevator return for Fire Department service
- smoke detectors at the return air system on each floor
- smoke detectors at the main air conditioning system fans.

The above protective systems are described in Part I of this report.

2. Off Hour Protection

As previously noted, smoke detectors are installed at the return air intakes in four locations on each floor. Tests were conducted to determine the effective time lapse for detection by initiation of smoke bombs. The most remote office area with different combinations of fans operating. As a result of these tests, it is current procedure to operate one return air fan to each quadrant of the building throughout the off-hour period. This procedure will permit detection of a fire in its incipient stage within a maximum of five minutes.

3. Proposed Life Safety Features

To further improve the life safety provisions with the Trade Center and to include protective measures required by Local Law 5, the following steps are underway.

Elevator Lobby Smoke Detectors

A contract for the installation of smoke detectors in each elevator lobby has been prepared and bids received. The activation of any detector would automatically cause all elevators within the bank serving that floor to return to their respective lobby to permit full use by the Fire Department.

Extension of Fire Alarm and Communication System

As previously noted in Part I, the present alarm system which included voice communication between the Police Deck as well as communications through speaker systems in the core corridors on each floor, will be extended to provide warble tone alarm within the office areas and message communications within the stairways. A contract for this work has been awarded and is underway.

Plenum Segregation

Where not presently installed, the walls delineating the corridors will be carried to the underside of the floor slab above to minimize smoke spread.

Stair Pressurization Studies

To provide the added safety of insuring smoke-free stairways, a study is underway to evaluate the feasibility and effectiveness of pressurizing the stairways relative to the office areas. This study includes a study of technical papers prepared throughout the world, a re-review of the tests conducted at 30 Church Street, an inspection of the 50-story Seattle bank building which has

an operational stair pressurization system, preliminary testing at the World Trade Center to determine the methodology and instrumentation required for conducting an in-situ survey of the World Trade Center stairs prototype system to pressurize 40 floors in one stairway.

Sprinkler Extension Provision

In addition to sprinklering the core area mail and storage rooms, supplementary fire standpipe and drainage risers will provide extension of the sprinkler system as future occupancy changes or as conditions may dictate.

4. Consultants Life Safety Survey of the World Trade Center

In addition to the studies and investigations performed by staff for life safety protection in the World Trade Center towers, a consultant was engaged by the Port Authority to make a survey. The consultant engaged for the survey was the National Loss Control Service Corporation, an organization which has performed many similar investigations for Insurance Companies and other organizations in the past.

The premises upon which this survey was conducted started with the realization that most occupants of buildings of this type will remain inside the complex for the duration of the fire incident. Thus, the building must provide safe refuge, readily accesible for all occupants, where a tenable atmosphere can be maintained. The consultant set as criteria that the basic requirements for an area to remain tenable are:

1. maintain structural integrity of the building;
2. absence of exposure to a direct flame;
3. presence of sufficient oxygen for life support;
4. absence of toxic combustion products at concentrations

sufficient to cause serious injury or even temporary disability; and,

5. absence of significant visible smoke.

In the consultant's survey of the Trade Center, he established that the structural fire resistance of the building is sufficient to make the probability of serious progressive structural collapse extremely remote, and the degree of vertical compartmentation effectively limits the spread of fire and its attendant oxygen depletion to the floor of fire origin. Adequate exit capacity for the fire floor along with the presence of the Fire Safety Plan to evacuate the fire floor and the floor above, limits the exposure of building occupants to direct fire effects. Therefore, the consultant concluded; "it is the spread of smoke and toxic combustion products that require principal attention from a life safety standpoint."

On the basis of these premises the consultant proceeded to study the effect of fires originating in different areas of the complex, and the effects of these fires on the life safety of the occupants. In completing his studies and evaluations of the World Trade Center Towers, which included a comparative analysis of the relative life safety of the occupants relative to conforming the towers with either the compartmentation option or sprinkler option of Local Law 5, the consultant concluded that either of the two fire protection options provided for under Local Law 5 would provide a good level of occupant life safety within the World Trade Center complex, provided that whichever is selected, it is supplemented by certain additional measures. In the case of the compartmentation option, the consultant recommended that this option be supplemented with the following additional features:

A) Sprinklering of rooms in the central corridor area

which could contribute excessive quantities of smoke to the corridor systems.

B) Doors which are normally kept open to the corridor system should be equipped with electro-magnetic "hold-open" devices and inter-connected to smoke detection devices to activate the closing of the door.

C) Provide fail-safe automatic door closers, arranged to close upon activation by smoke detectors for the overhead rolling fire doors separating the below grade truck door from the elevator lobby.

D) Perform an investigation to determine the optimum mode of operation of the building air conditioning system to remove smoke from the central core compartments without contaminating adjacent areas.

In the case of the sprinkler option, the consultant recommended that this option be supplemented with items B, C and D noted above for the compartmentation option, and that in addition, automatic smoke detection, in the immediate vicinity of elevators at each floor level, should also be provided.

5. Summary and Conclusions

As a result of the studies and investigations performed by both staff and consultants, it has been concluded that the World Trade Center Towers do provide life safety protection for its inhabitants. This life safety protection can be enhanced by the incorporation of several improvements into the structures as follows:

1. The openings between floors of telephone closets, which was a source of fire spread during the February 13, 1975 fire should be closed. This work has been accomplished to prevent any reoccurrences of a similar condition;

2. In addition, the Port Authority will proceed with the compartmentation option of Local Law 5 including all of its requirements for fire alarm, communications and stairway pressurization;

3. Sprinklering of all storage rooms, janitor closets, mail rooms and file rooms in the central core of each floor.

4. Building additional sprinkler capacity and provisions for extension of a sprinkler system to any area of such usage requiring it in the event of an occupancy change.

5. Equipping those doors which are normally kept open to the corridor system, such as doors at consumer service areas, with electromagnetic "hold open" devices which would be activated by smoke detectors to close the doors.

6. Providing fail-safe automatic doors closers, arranged to close upon activation by smoke detectors, for the overhead rolling fire doors separating the below-grade truck dock from the elevator lobby.

7. Developing an optimum mode of operation of the building air-conditioning system to remove smoke from the central core compartments without contaminating adjacent areas.

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In July 1975 a Temco Maintenance Company employee was charged in an indictment with setting the February 13, 1975 fire as well as five subsequent World Trade Center fires.

Extent of Fire Damage

The fire damage occurred mainly on the 11th floor, in the southeast quadrant. Whatever fire damage occurred on other floors was generally limited to the telephone closet in the southeast quadrant of floors 9 through 14 and a small portion of spaces immediately adjacent to the telephone closets.

Smoke damage occurred in varying degrees in the adjoining sections of the 11th floor; elsewhere, the significant smoke damage occurred on the 10th, 12th, 13th and 14th floors. Smoke damage on floors 15 through 23 was generally limited to the area of the telephone closet in the southeast quadrant and a small portion of the tenant spaces immediately adjacent, in decreasing degrees.

Existing Building System Evaluation -
World Trade Center Building System - Building Code

For further information there follows a description of the World Trade Center building systems for fire protection and extinguishment, together with an account of the Port Authority's conformance to the standards established by the New York City Building Code, including the amendments known as Local Law 5/73, even though the State and its agencies, such as the Port Authority, are not subject to City building codes.

References are made in various places to the 1968 building code, since that code would have applied to construction generally at the time the World Trade Center was built. A separate discussion addresses itself to the amendments of 1973, i.e. Local Law No. 5. Following is a description of the existing systems at the World Trade Center:

Air Distribution Systems

The Trade Center air distribution systems, in addition to conforming to all the 1968 NYC Building Code requirements, also possess an additional mode of operation which can be utilized to assist in controlling smoke from a fire. In this mode the return air shaft and fan systems are used to exhaust from the office spaces to the exterior of the building. The core system is also operated to provide outside air to the corridors.*

Fire Standpipe System

The standpipe system consists of manually activated fire pumps rated at 750 GPM each located at the Service Level, 7th Floor, 41st Floor and 75th Floor. In addition, there

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* There are four mechanical equipment rooms serving each tower. These equipment rooms, which contain the air handling systems, are located on the 7th, 41st, 75th and 108th floors. The air distribution from these floors can be generally divided into three sub-systems, the peripheral, the interior and the core. The peripheral system serves the floor area around the exterior wall and feeds up from the ceiling of the floor below to induction units at the exterior wall. The interior system serves the remaining office floor area through ductwork located above the hung ceiling with air outlets combined with the light fixtures. Air returns to the equipment room through other light fixtures into the ceiling area, which acts as a plenum, and from the plenum to shafts running vertically at the building core. The core system serves the corridor and elevator lobbies.

are 5,000 gal. water storage tanks located on the 20th Floor, 41st Floor, 75th Floor and roof. There are also a minimum of three fire hose racks on each floor capable of reaching every part of that floor. The standpipe system conforms to the 1968 Building Code. Initially, during the fighting of the fire, Tower A pump experienced some difficulty with the speed control panel. Tower B pump, which was designed to be operable also for Tower A, was then used. The Tower A pump was returned to use during the fire fighting, without difficulty. The standpipe system functioned to the complete satisfaction of the Fire Department throughout.

Smoke Detectors

Smoke detectors were installed in each return air fan discharge duct and each supply unit. Upon actuation any one of these detectors will shut down all the ventilation fans within the respective quadrant of the mechanical room and initiate a print-out and visual and audible alarms in the central control station. This installation is in conformance with the 1968 Building Code.

In addition to the smoke detectors previously noted, under a contract prepared prior to enactment of Local Law 5, detectors with supervised circuits have been installed at 4 locations on each floor of the Tower Buildings. These detectors are located above the hung ceiling directly in front of a return air duct intake and indicate an alarm condition, by floor, at the Port Authority Police Desk. In the building zone in which the fire occurred, detectors were installed and operational on Floors 9 through 19. These detectors initiated a print-out at the police desk.

Elevator Control

All passenger elevator cars are capable of being recalled to their respective lobbies. This control over-rides all individual floor hall calls, prevents heat from calling a car to a "fire floor" and makes the car available for manual operation by building personnel and the Fire Department.

This is in excess of the requirements of the 1968 Code, which required only one elevator capable of serving each floor equipped for emergency return and Fire Department Service.

Fire Alarm System

On each floor of each of the World Trade Center buildings, at a central corridor location, there was a fire alarm emergency telephone which connected with a control center next to the Police Desk on the lower level of Tower A. (In addition, the Port Authority has applied on telephones in its own offices, and has distributed to tenants for their application on their telephones, a conspicuous red label giving the telephone number of the Police Desk to call in case of emergency.) An interior fire alarm system including voice communication has been installed on each floor in the core corridor. Incoming fire calls to the control center illuminate the indicating lamp of a particular fire station and sound an audible signal. In addition, an emergency public address system provides communication from the control center to all locations equipped with loudspeakers, as selected by the control center operator. The system also can transmit, through two individual microphones, different messages to selected loudspeaker areas. It can also receive communications from the elevator starter panels. Pre-recorded announcements can be transmitted through this system and announcements originating from the elevator starter panels can be transmitted through this console to selected loudspeakers. Fire alarm warble tones can be transmitted to any floor or floors from one of these microphones.

The control console is equipped with separate indicator lights and switches for each area. The indicating lights provide visual information as to which loudspeaker area is in operation. In addition, a warning light system is included to indicate failure of any of the amplifiers located in a remote location. These amplifiers are tested automatically at intervals or can be tested manually by operating personnel. Visual indication of amplifier failure is also provided on the front panel of each power amplifier.

Requirements of Local Law No. 5/73

The fire safety amendments to the New York City Building Code embodied in Local Law 5 adopted in 1973 prescribe various measures to be complied with by various dates. The Port Authority has complied with those for which compliance dates have already occurred, and in fact had incorporated in the World Trade Center design a number of such measures before they were adopted under Local Law 5. Some examples are as follows.*

Interior fire alarm system, including voice communication:

The World Trade Center was designed and constructed with a fire alarm and voice communication system in the corridors before any such system was required by code. Local Law 5 required such a system to be installed, including its extension into office spaces as well as stairways. A contract has been prepared and awarded to extend the system into the office spaces and stairways.

Automatic "homing" of elevators, and elevator in readiness:

Manual controls presently installed in the World Trade Center permit recall of all elevators to their home floor, overriding any manual or heat activation of call buttons, where they can be placed under the command of the Fire Department for fire fighting operations. This too was beyond the requirements of the 1968 code. Local Law 5 now requires automatic homing of elevators when

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* While combustibility of furnishings is not dealt with in Local Law 5 or other parts of the New York City Building Code, the Port Authority addressed itself to this problem in planning the World Trade Center and after extensive study adopted and applied standards rigidly limiting its own furnishings to a low rate of flammability. A copy of the Port Authority's flammability standards was communicated to tenants, pointing out the advisability of their use.

a smoke detector, to be installed in the elevator lobby of each floor, is activated. Such additional smoke detectors and automatic activation will be installed at the World Trade Center.

Sprinklers or Compartmentation and Other Measures

Under Local Law 5, owners of buildings (existing and future) of a class in which the World Trade Center would be included, are given the option of sprinklering throughout or of installing certain measures such as compartmentation of each floor into maximum areas of 7,500 square feet each separated by fire rated partitions, as well as smoke detectors as above described and pressurization of stairwells.

In certain types of locations, such as below grade areas and restaurants, and other commercial spaces, sprinklering is required without allowance for an option, and in those locations the World Trade Center as originally constructed included sprinklers.

Fire Safety Plan

Local Law 5 calls for a plan of regular fire drills and evacuation procedures, approved by the City, under the supervision and control of a building fire safety director and one or more deputies. The Port Authority's plan exceeds these requirements, and the New York Board of Fire Underwriters, after investigating the February 13th fire, observed: "The Fire Safety Program of the World Trade Center is an excellent one." The Board, while recommending examination of additional safety measures, such as limiting combustibility of furnishings, further observed: "In the overall, these towers may be considered as among the safest buildings in New York City." See Page 10 of The New York Board of Fire Underwriters report.

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PART II

Evaluation of Life Safety

The World Trade Center contains a complete fire protection and life safety installation which is itemized in the following sections. Furthermore, as indicated herein, additional measures will be implemented to enhance the present standards.

1. Existing Life Safety Features

As noted in Part I of this report, the World Trade Center has extensive life safety features which are in accordance with and beyond the requirements of New York City Code. These features include the following:

- fireproof construction
- fire standpipe system
- smoke purge mode for air conditioning systems
- fire alarm and voice communication system
- sprinklers for restaurants, concession areas, and other public areas
- elevator return for Fire Department service
- smoke detectors at the return air system on each floor
- smoke detectors at the main air conditioning system fans.

The above protective systems are described in Part I of this report.

2. Off Hour Protection

As previously noted, smoke detectors are installed at the return air intakes in four locations on each floor. Tests were conducted to determine the effective time lapse for detection by initiation of smoke bombs. The most remote office area with different combinations of fans operating. As a result of these tests, it is current procedure to operate one return air fan to each quadrant of the building throughout the off-hour period. This procedure will permit detection of a fire in its incipient stage within a maximum of five minutes.

3. Proposed Life Safety Features

To further improve the life safety provisions with the Trade Center and to include protective measures required by Local Law 5, the following steps are underway.

Elevator Lobby Smoke Detectors

A contract for the installation of smoke detectors in each elevator lobby has been prepared and bids received. The activation of any detector would automatically cause all elevators within the bank serving that floor to return to their respective lobby to permit full use by the Fire Department.

Extension of Fire Alarm and Communication System

As previously noted in Part I, the present alarm system which includes voice communication between the Police Deck as well as communications through speaker systems in the core corridors on each floor, will be extended to provide warble tone alarm within the office areas and message communications within the stairways. A contract for this work has been awarded and is underway.

Plenum Segregation

Where not presently installed, the walls delineating the corridors will be carried to the underside of the floor slab above to minimize smoke spread.

Stair Pressurization Studies

To provide the added safety of insuring smoke-free stairways, a study is underway to evaluate the feasibility and effectiveness of pressurizing the stairways relative to the office areas. This study includes a study of technical papers prepared throughout the world, a re-review of the tests conducted at 30 Church Street, an inspection of the 50-story Seattle bank building which has

an operational stair pressurization system, preliminary testing at the World Trade Center to determine the methodology and instrumentation required for conducting an in-situ survey of the World Trade Center stairs prototype system to pressurize 40 floors in one stairway.

Sprinkler Extension Provision

In addition to sprinklering the core area mail and storage rooms, supplementary fire standpipe and drainage risers will provide extension of the sprinkler system as future occupancy changes or as conditions may dictate.

4. Consultants Life Safety Survey of the World Trade Center

In addition to the studies and investigations performed by staff for life safety protection in the World Trade Center towers, a consultant was engaged by the Port Authority to make a survey. The consultant engaged for the survey was the National Loss Control Service Corporation, an organization which has performed many similar investigations for Insurance Companies and other organizations in the past.

The premises upon which this survey was conducted started with the realization that most occupants of buildings of this type will remain inside the complex for the duration of the fire incident. Thus, the building must provide safe refuge, readily accesible for all occupants, where a tenable atmosphere can be maintained. The consultant set as criteria that the basic requirements for an area to remain tenable are:

1. maintain structural integrity of the building;
2. absence of exposure to a direct flame;
3. presence of sufficient oxygen for life support;
4. absence of toxic combustion products at concentrations

sufficient to cause serious injury or even temporary disability; and,

5. absence of significant visible smoke.

In the consultant's survey of the Trade Center, he established that the structural fire resistance of the building is sufficient to make the probability of serious progressive structural collapse extremely remote, and the degree of vertical compartmentation effectively limits the spread of fire and its attendant oxygen depletion to the floor of fire origin. Adequate exit capacity for the fire floor along with the presence of the Fire Safety Plan to evacuate the fire floor and the floor above, limits the exposure of building occupants to direct fire effects. Therefore, the consultant concluded; "it is the spread of smoke and toxic combustion products that require principal attention from a life safety standpoint."

On the basis of these premises the consultant proceeded to study the effect of fires originating in different areas of the complex, and the effects of these fires on the life safety of the occupants. In completing his studies and evaluations of the World Trade Center Towers, which included a comparative analysis of the relative life safety of the occupants relative to conforming the towers with either the compartmentation option or sprinkler option of Local Law 5, the consultant concluded that either of the two fire protection options provided for under Local Law 5 would provide a good level of occupant life safety within the World Trade Center complex, provided that whichever is selected, it is supplemented by certain additional measures. In the case of the compartmentation option, the consultant recommended that this option be supplemented with the following additional features:

A) Sprinklering of rooms in the central corridor area

which could contribute excessive quantities of smoke to the corridor systems.

B) Doors which are normally kept open to the corridor system should be equipped with electro-magnetic "hold-open" devices and inter-connected to smoke detection devices to activate the closing of the door.

C) Provide fail-safe automatic door closers, arranged to close upon activation by smoke detectors for the overhead rolling fire doors separating the below grade truck door from the elevator lobby.

D) Perform an investigation to determine the optimum mode of operation of the building air conditioning system to remove smoke from the central core compartments without contaminating adjacent areas.

In the case of the sprinkler option, the consultant recommended that this option be supplemented with items B, C and D noted above for the compartmentation option, and that in addition, automatic smoke detection, in the immediate vicinity of elevators at each floor level, should also be provided.

5. Summary and Conclusions

As a result of the studies and investigations performed by both staff and consultants, it has been concluded that the World Trade Center Towers do provide life safety protection for its inhabitants. This life safety protection can be enhanced by the incorporation of several improvements into the structures as follows:

1. The openings between floors of telephone closets, which was a source of fire spread during the February 13, 1975 fire should be closed. This work has been accomplished to prevent any reoccurrences of a similar condition;

2. In addition, the Port Authority will proceed with the compartmentation option of Local Law 5 including all of its requirements for fire alarm, communications and stairway pressurization;

3. Sprinklering of all storage rooms, janitor closets, mail rooms and file rooms in the central core of each floor.

4. Building additional sprinkler capacity and provisions for extension of a sprinkler system to any area of such usage requiring it in the event of an occupancy change.

5. Equipping those doors which are normally kept open to the corridor system, such as doors at consumer service areas, with electromagnetic "hold open" devices which would be activated by smoke detectors to close the doors.

6. Providing fail-safe automatic doors closers, arranged to close upon activation by smoke detectors, for the overhead rolling fire doors separating the below-grade truck dock from the elevator lobby.

7. Developing an optimum mode of operation of the building air-conditioning system to remove smoke from the central core compartments without contaminating adjacent areas.